Development of X-Ray Mirror Segments for the Constellation-X Mission

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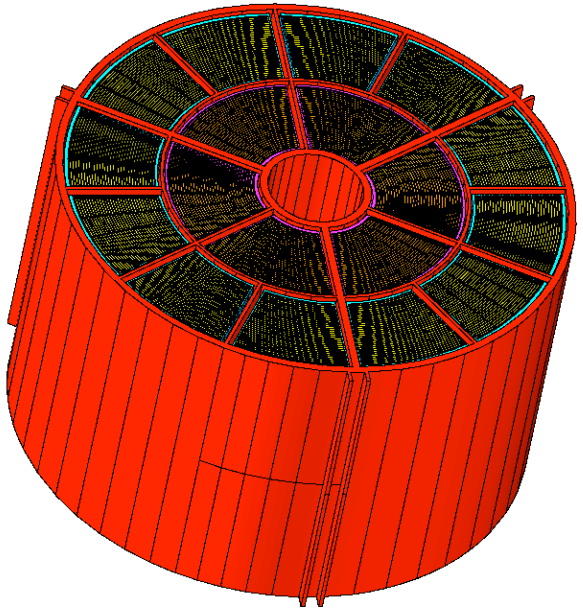
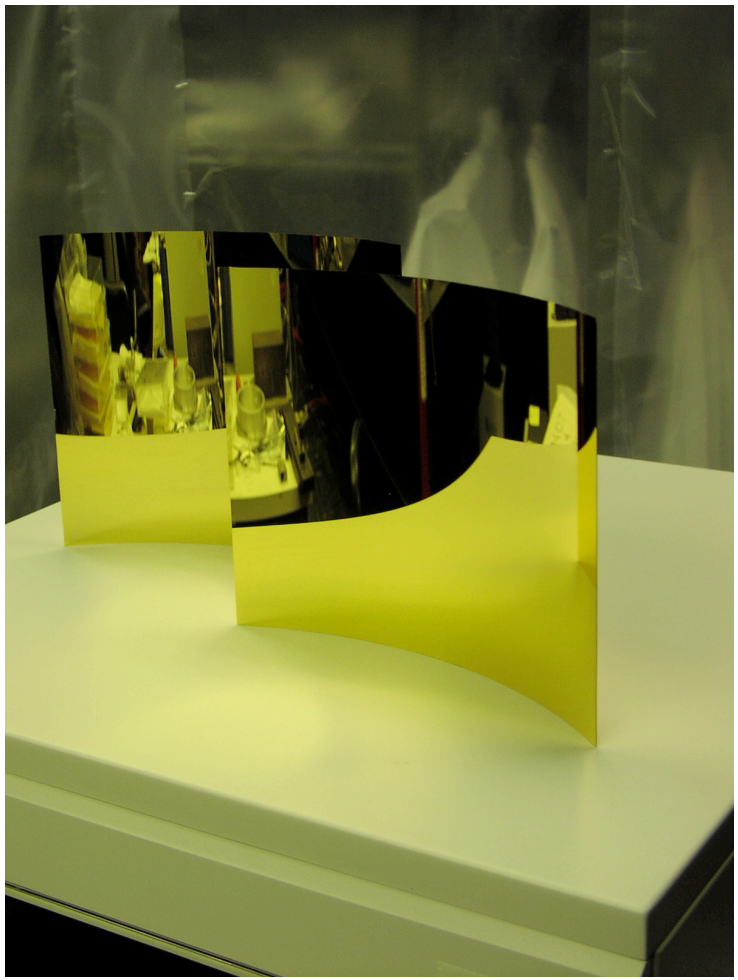
Constellation-X Spectroscopic X-ray Telescopes (SXT)

- *Total Number of Mirror Assemblies: 4*
- *Total Effective Photon Collection Area at 1 keV: 3 m^2 or 0.75m^2 for each mirror assembly*
- *Angular Resolution: 15″ HPD at observatory level; 12″ for the mirror assembly; 10″ for mirror segments*
- *Total Physical Mirror Area: ~1000 m^2*
- *Baseline Design: Each mirror assembly*
  - *1.6m in diameter*
  - *10m focal length*
  - *230 nested shells, each shell segmented into 6 (inner) or 12 (outer) segments*
  - *~4,000 mirror segments*
  - *Smallest segment: 20cm by 20cm*
  - *Largest segment: 20cm by 40cm*

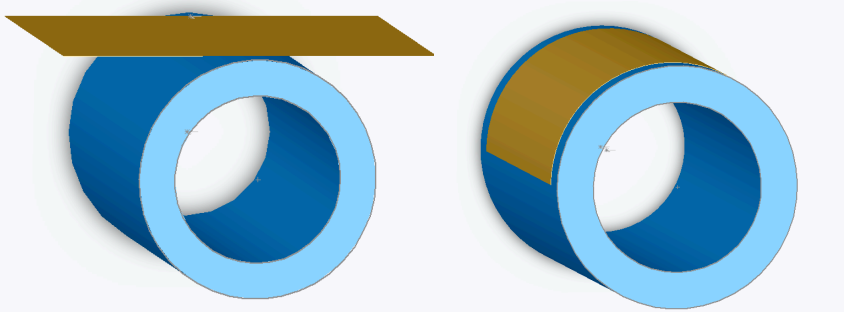


Mirror Segment Requirements



- *Mass:* ***Mirror segments can only be about 0.4mm in thickness (using borosilicate glass), corresponding to an areal density of 1 kg/m^2***
- *Figure:*
  - ***Sag (2nd order peak to valley) must be within 0.2 m of the theoretical value***
  - ***After removing the sag, the residual axial slope error must be < 2″ rms***
  - ***Microroughness must be ~6Å rms (0 to 0.3mm length scale)***

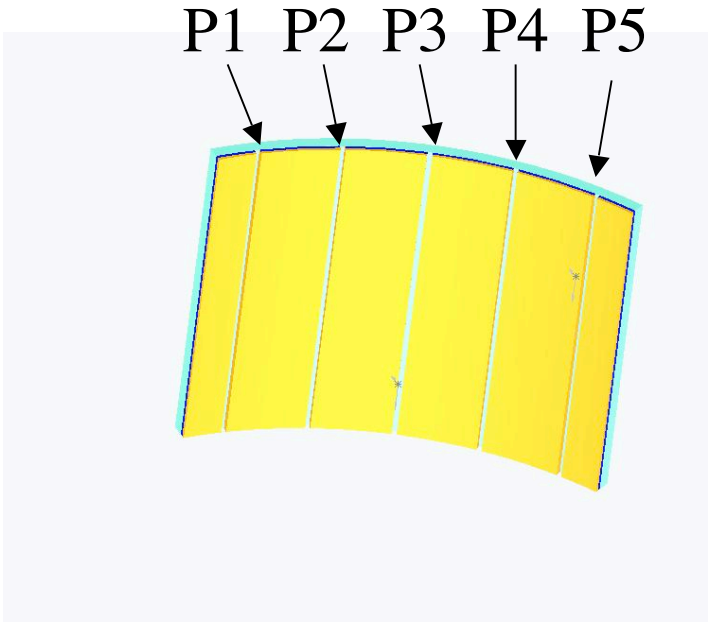
Technical Approach



- *Create a substrate by slumping a flat glass sheet onto a forming mandrel. This substrate provides the overall figure for the mirror segment*
- *Eliminate high frequency errors of the substrate using an epoxy replication*

Preliminaries

Five axial figure scans using a Wyko interferrometer analyzed in both spatial and frequency domains



$$\sigma^2 = \int psd(f) \bullet df$$

$$\sigma^2 = 4\pi^2 \int psd(f) \bullet f^2 \bullet df$$

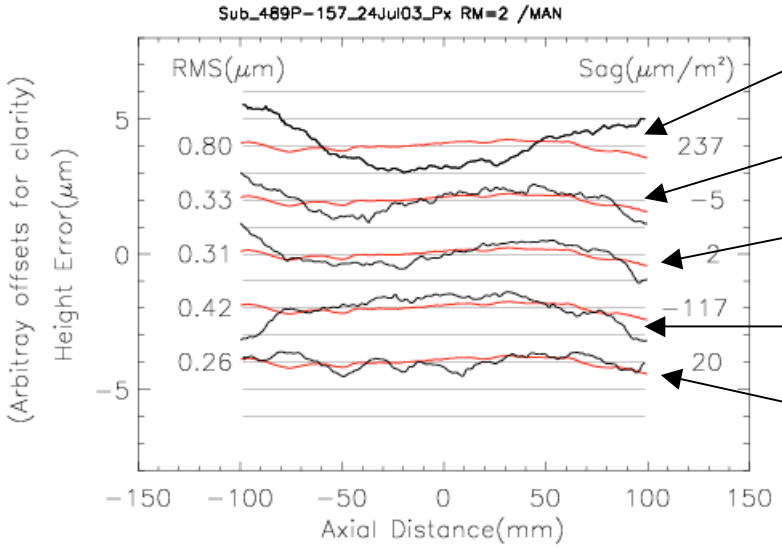
$$\sigma^2 = \frac{4\pi^2}{\log_{10}(e)} \int psd(f) \bullet f^3 d[\log_{10}(f)]$$

Define Modified PSD as

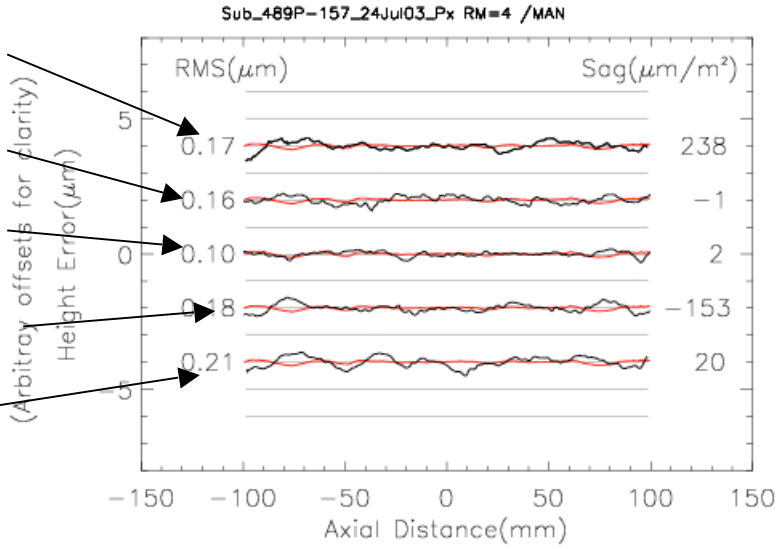
$$\frac{d\sigma^2}{d[\log_{10}(f)]} = \frac{4\pi^2}{\log_{10}(e)} \bullet psd(f) \bullet f^3$$

A Typical Primary Substrate

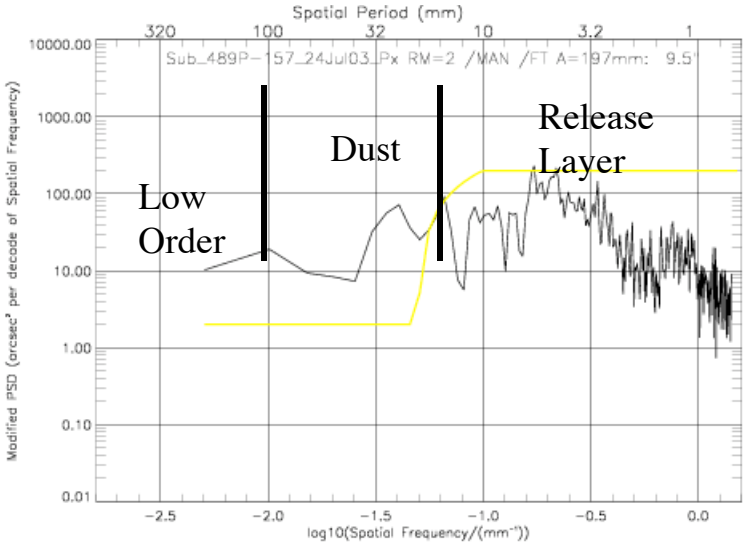
Only tilt (1st order, tilt) removed

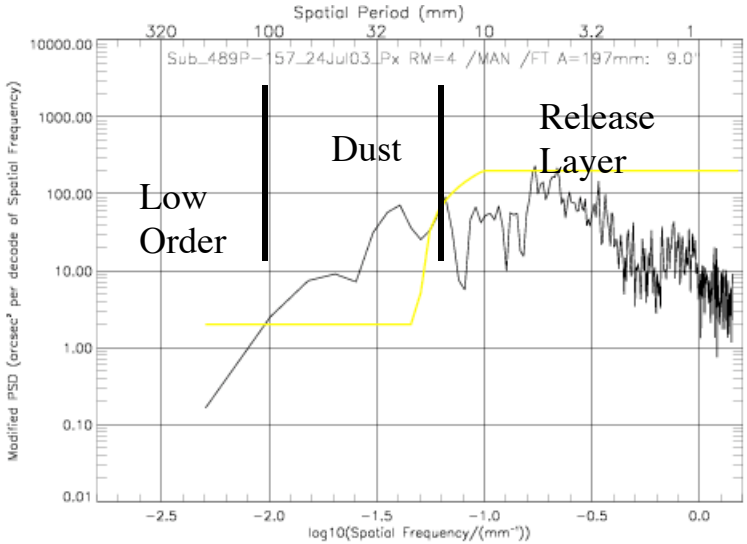


1st, 2nd, and 3rd orders removed

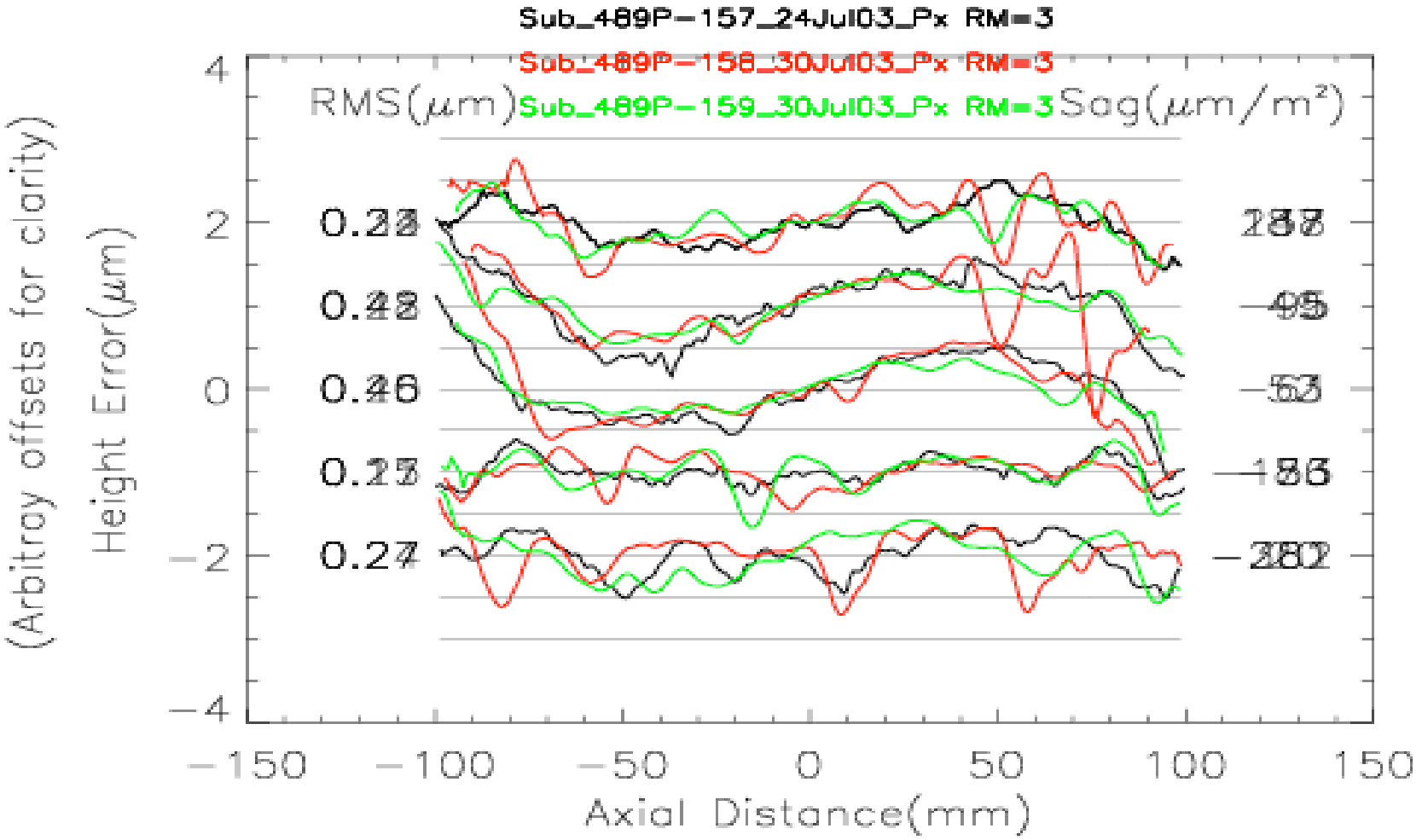


P1
P2
P3
P4
P5

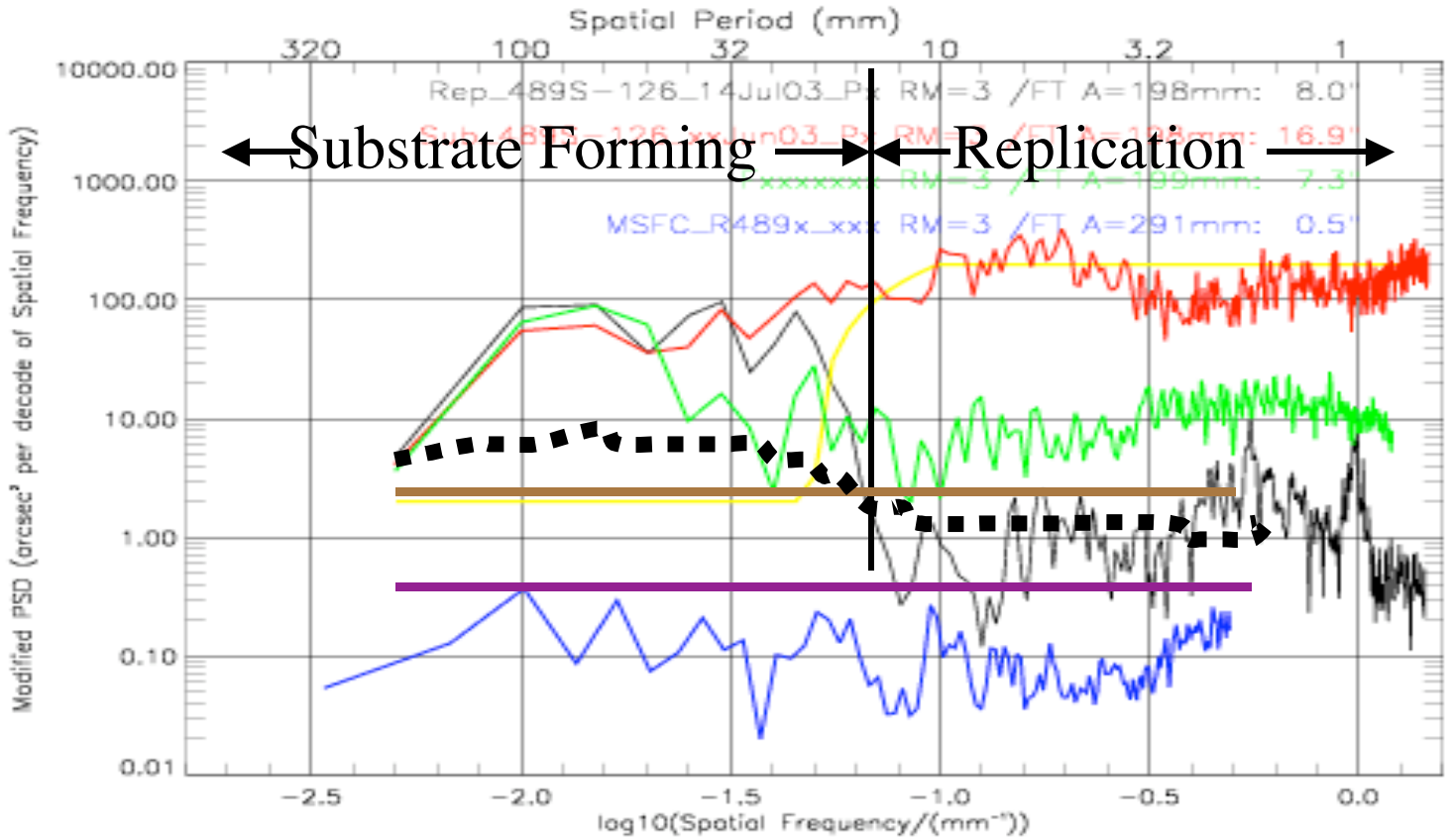




Three Consecutively Formed Substrates



A Typical Substrate and Replica



- Red: substrate;
- Black: replica;
- Green: forming mandrel;
- Blue: Zeiss replication mandrel;

- Yellow: substrate requirement;
- Brown: Corresponding to a 12″ HPD (Con-X Requirement)
- Purple: Corresponding to a 5″ HPD (Con-X Goal)

Status and Outlook

- ***Forming and Replication Mandrels***
  - ***Three 4″ HPD segment replication mandrels have been fabricated and delivered by Zeiss***
  - ***Matching 4″ HPD forming mandrels are on order and are being fabricated by Schott and Zeiss***
- ***Substrate Forming***
  - ***Correcting low order errors (Forming Mandrel Distortion, Error due to Distortion caused by gravity and other forces during measurements)***
  - ***Correcting middle order errors (Cleaning up the forming environment)***
- ***Replication (correcting high frequency error of substrate)***
  - ***Using 5 to 10-um epoxy thickness***
  - ***Using slow and gentle cure cycles to reduce epoxy***

We expect to meet, and possibly exceed, Constellation-X requirements within a year